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Abstract

In order to evaluate the effect of nitrogen (N) with late-season fertilizer applications in corn, grain yield and grain filling parameters were evaluated for three genotypes under three N levels. Hybrids with different release years (3394, 1990s; P1151, 2000s; and P1197, 2016) and contrasting N application scenarios (zero-N, N at flowering, and N two weeks after flowering) were evaluated in two studies (dryland and irrigated) at the Ashland Bottoms Research Farm, Manhattan, KS, 2017 season. Results showed that under N stress conditions, the absence of N fertilization in corn significantly reduced yields, by affecting both grain number (GN) and grain weight (GW). Regarding genotypes, a positive trend was found between the year of release of the hybrid and yields, with greater yields for the modern hybrid (i.e., 206 bu/a for P1197). In respect to the grain filling process, N fertilization significantly increased the grain filling duration (GFD), without changes in the grain filling rate (GFR). Consequently, increments in GW were more related to changes in GFD rather than on the GFR.

Keywords

Late N application, corn, grain filling, late-nitrogen application

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Summary

In order to evaluate the effect of nitrogen (N) with late-season fertilizer applications in corn, grain yield and grain filling parameters were evaluated for three genotypes under three N levels. Hybrids with different release years (3394, 1990s; P1151, 2000s; and P1197, 2016) and contrasting N application scenarios (zero-N, N at flowering, and N two weeks after flowering) were evaluated in two studies (dryland and irrigated) at the Ashland Bottoms Research Farm, Manhattan, KS, 2017 season. Results showed that under N stress conditions, the absence of N fertilization in corn significantly reduced yields, by affecting both grain number (GN) and grain weight (GW). Regarding genotypes, a positive trend was found between the year of release of the hybrid and yields, with greater yields for the modern hybrid (i.e., 206 bu/a for P1197). In respect to the grain filling process, N fertilization significantly increased the grain filling duration (GFD), without changes in the grain filling rate (GFR). Consequently, increments in GW were more related to changes in GFD rather than on the GFR.

Introduction

In corn, yield improvement across decades was accompanied by an increase in plant nitrogen (N) uptake, with modern hybrids absorbing more N during reproductive stages (Ciampitti and Vyn, 2012; Haegele, 2013), while delaying N remobilization to the grain until later in the growing season. Evaluation on a range of N management is still necessary to understand the optimal approach for simultaneously improving both yields and N use efficiency (NUE).

From a yield component perspective, final grain yield is the result of grain number per unit area (GN) and final grain weight (GW). Although it is accepted that GN is the primary component for grain yield determination (Borrás et al., 2004), GW can be responsible for important variations in final grain yield in corn. However, results on the effect of N supply on grain filling dynamics in corn are still scarce.

Evaluation on the effect of N with late-season applications can increase our understanding on how N is impacting yields: 1) more grains per plant, or 2) more weight of the grains, or via improvement in both plant yield components. Less is known about how N is impacting corn during the grain filling process, from zero weight (lag phase) until final grain weight is achieved (black layer). The objective of this research study was to evaluate grain filling in corn under three contrasting N scenarios (with and without late-season application, and a check with no N application) for three corn hybrids (from distinct decades) with the goal of determining yield response and grain filling rate.

Procedures

Two field experiments were conducted at the Ashland Bottoms Research Farm, Manhattan, KS, 2017 (one under irrigation and one rainfed). Soil analyses were conducted pre-planting to characterize initial conditions. Overall, the area presented pH of 5.9, soil organic matter (SOM) 1.34%, 50 ppm of phosphorus (P) (Mehlich), and 158 ppm of potassium (K) at 6-inch soil depth.

A split-plot design with two factors was evaluated, genotype with three levels in the main plot, and fertilizer N rate with three levels in the sub-plot. For genotype, three hybrids with different release years (3394, 1990s; P1151, 2000s; and P1197, 2016) and three contrasting N scenarios (zero N, N at flowering, and N two weeks after flowering) were evaluated in both studies. The study was planted on May 5, 2017, in plots of 4 rows, 30 in. apart, and size of 10-ft wide × 70-ft long. For the two fertilized treatments, an initial 50 lb/a was added at planting, and a second application was added at V6 growth stage (50 lb/a and 100 lb/a for dryland and irrigated, respectively). Depending on the treatment, the last application (22 lb/a and 44 lb/a for dryland and irrigated, respectively) was performed at silking or two weeks after this growth stage. Total fertilizer N rate applied for the treatments receiving N was 122 lb/a for the rainfed and 194 lb/a for the irrigated condition. The experimental area was kept free of weeds, pests, and diseases during the growing season.

For grain filling determination, since R2 growth stage, one ear was collected every 3 to 4 days from each treatment combination, until harvest. To understand if late-N can still impact final grain weight, ten kernels from the central portion of the ear were sampled to track changes in kernel dry weight and water volume during the entire period.

At the end of the growing season, grain yield was determined with a plot combine (from two center rows that were 70-ft long), while simultaneously four plants per plot were hand harvested for determining yield components (grain number, grain weight, and harvest index).

Results were subjected to an analysis of variance (ANOVA) to test the effect of fertilizer N rates, genotypes, and their interaction in all the measured variables. Grain filling rate (GFR) and grain filling duration (GFD) were estimated fitting a bi-linear model [equations (1) and (2)] with grain dry weight plotted on a day-time basis from silking to harvest maturity:

$$\text{Grain weight (mg/grain)} = a + b \times d \qquad \text{for } d<c \qquad [1]$$
$$\text{Grain weight (mg/grain)} = a + b \times c \qquad \text{for } d>c \qquad [2]$$

where d are the days after silking, a is the y-intercept (mg/grain), b is the GFR (mg/grain d^{-1}), and c is the total GFD (in days).

Results

Grain Yield and Numerical Components

Table 1 summarizes average yields and yield components for fertilizer N rate levels (N) and corn hybrids (H) evaluated in the experiment. Differences in yield were significant between N and H treatments ($P \leq 0.001$ and $P \leq 0.05$, respectively). As expected, fertilized treatments differed from the zero N treatment, while there were no significant differences in average yields between late-N treatments. In respect to genotypes, a positive trend was found between the year of release of the hybrid and yields, from 176 bu/a for 3394 (early 1990s) to 206 bu/a for P1197 (current).

Regarding yield components, significant differences between N levels and genotypes were found for grain number (GN) ($P \leq 0.001$ and $P \leq 0.01$, respectively), and between N treatments for grain weight (GW) ($P \leq 0.001$). Taken as a whole, final GW did not differ between genotypes, reflecting that yield variations among H were primarily driven by the number of grains per ear defined around silking. However, GN and GW were both affected by the absence of N fertilization, suggesting that GW reductions could have a considerable effect on yields particularly in N stress environments.

Across all treatment and hybrid combinations, GN and GW were both positively correlated with final grain yield ($R^2 = 0.58$ and $R^2 = 0.43$, respectively) in agreement with other previous studies (Andrade et al., 1996; Tollenaar et al., 2000) (Figure 1A and B). A linear correspondence between both components was observed ($R^2 = 0.43$) (Figure 2), indicating that the period around flowering is critical for defining grain number per plant and potential grain size.

Grain Filling Rate and Duration

Increments in GW were more related to changes in GFD rather than in the GFR ($r = 0.28$, $p = 0.043$ and $r = 0.18$, $p = 0.187$, respectively). Nitrogen supply significantly increased GFD (Figure 3), whereas no differences were observed for GFR, reflecting that this trait is more genotype-dependent and less sensitive to management changes. Furthermore, GFR was negatively correlated with GFD ($r = -0.55$), with similar rates across H and extended length for the modern genotype (P1197, Table 1). Overall, under N stress conditions, shorter GFD was the primary factor for the reduction in final GW.

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Table 1. Analysis of variance and means for yield (15.5% moisture), grain number, grain weight, grain filling rate, and duration for three nitrogen (N) levels and three hybrids (H)

Factor	Yields	Grain number	Grain weight	Grain filling rate	Grain filling duration
	bu/a	grains/m^2	mg/grain	mg/°d/grain	days
0 (Zero) N	120 b	2927 b	220 b	7.08 a	45 b
N at flowering	234 a	4017 a	277 a	7.3 a	49 a
N 2 weeks after flowering	223 a	4195 a	276 a	7.25 a	49 a
3394	176 b	3285 b	254 a	7.4 a	46 b
P1151	195 ab	4021 a	252 a	7.23 a	47 ab
P1197	206 a	3833 a	266 a	7.01 a	49 a
Sources of variation					
Nitrogen	***	***	***	Ns	**
Hybrid	*	**	Ns	Ns	*
N × H	Ns	Ns	*	**	Ns

Different letters indicate significant differences at $P \leq 0.05$.
+ Significant at $P \leq 0.1$; × significant at $P \leq 0.05$; ** significant at $P \leq 0.01$; *** significant at $P \leq 0.001$, Ns: non-significant.

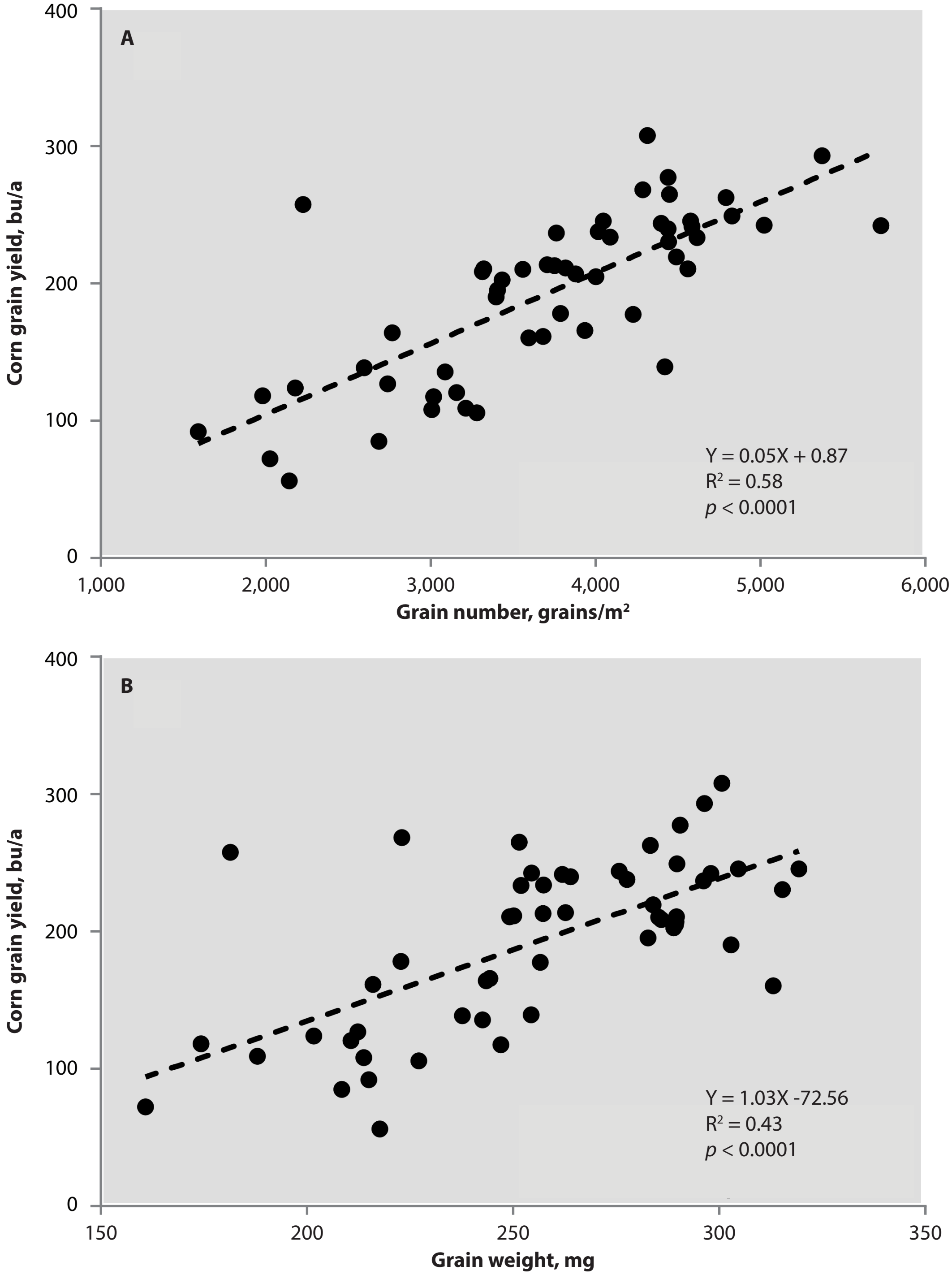

Figure 1. Relationship between grain yield for corn against the number of grains per unit area (A) and final grain weight (B), across all treatments combinations.

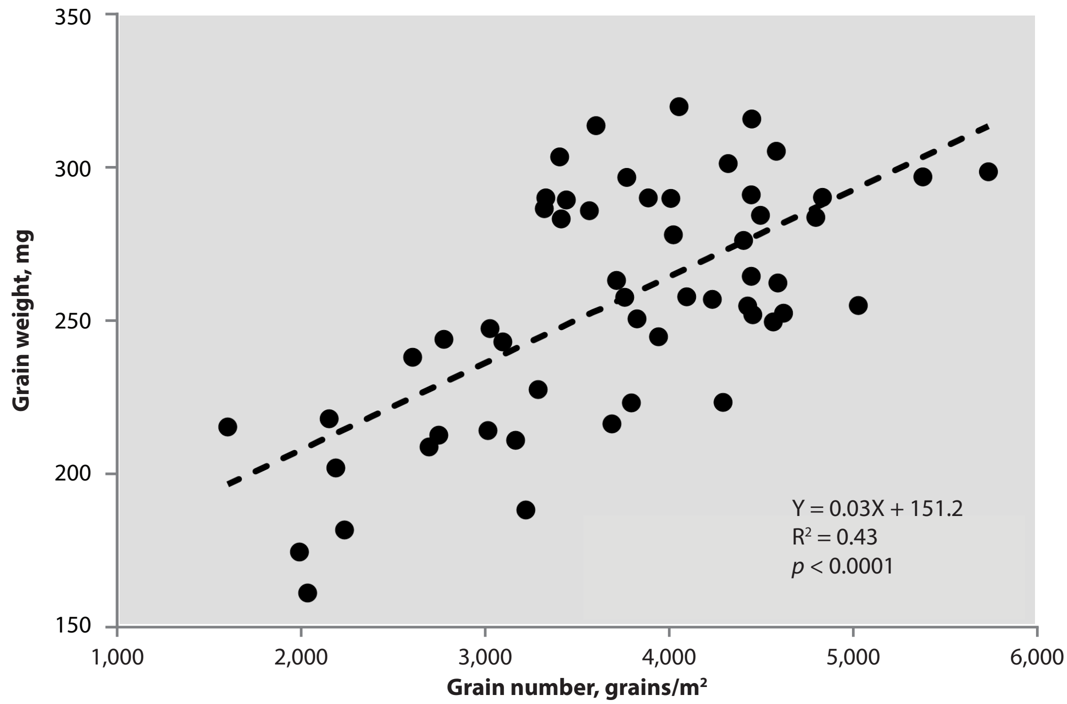

Figure 2. Relationship between final grain weight and number of grains per unit area, across all treatments combinations.

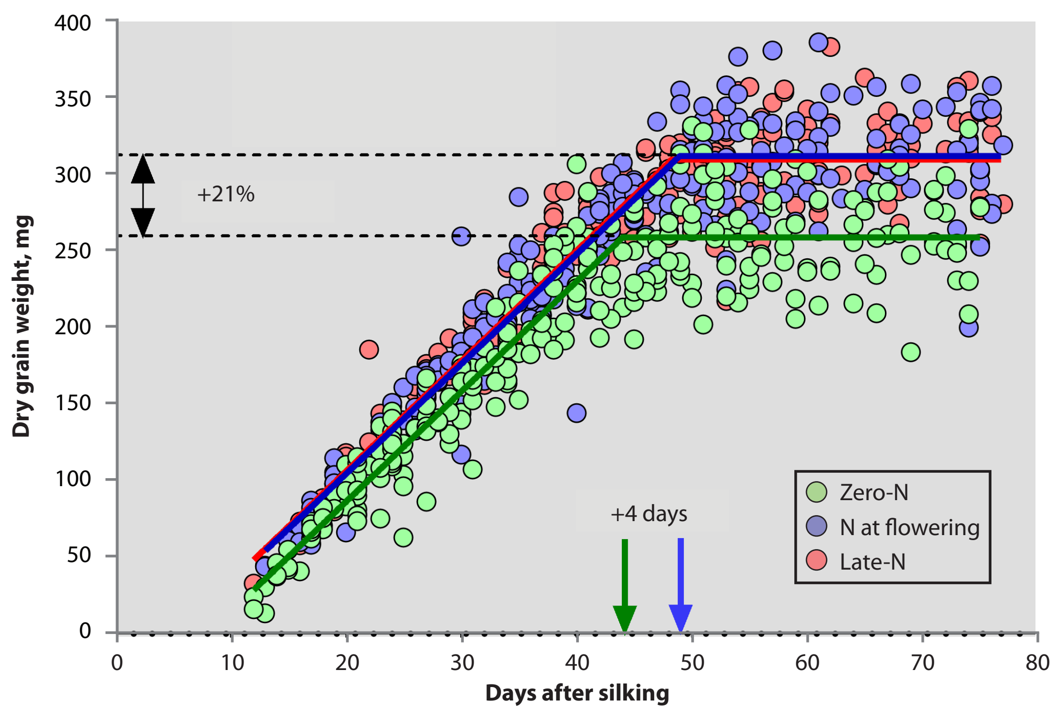

Figure 3. Evolution of grain dry weight on a day-time basis from silking to harvest maturity, sampled from the central portion of the ear, for three nitrogen (N) treatments.